Flight Loads & Environments Initiative

(a work in progress)

Daniel Kaufman
NASA GSFC

Dennis Kern
NASA JPL

Presentation for the 2005
Spacecraft & Launch Vehicle Dynamic Environments Workshop

Flight Loads & Environments Initiative

- Objectives
- Actual Process
- Historical Background
- Some Facts/Findings on Loads and Environments
- Proposed Process

Flight Loads & Environments Initiative

- Objectives

Primary:

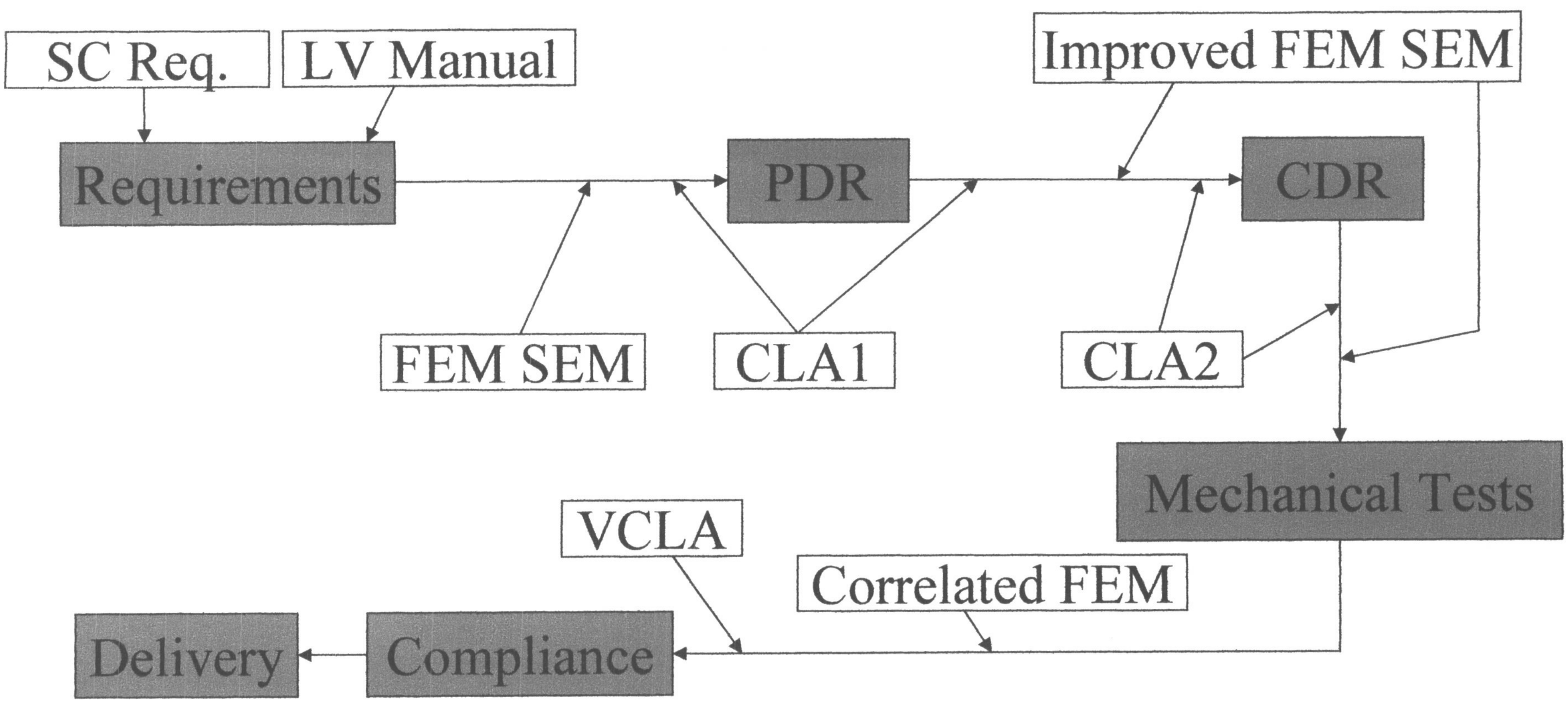
Reduce the cost per effective payload (PL) mass into orbit (CPMO) by improving launch vehicle (LV) loads and environments process in support of the PL .

Secondary:

Design and implement a light weight non intrusive force measurement device (FMD) for standard use in flight and test

Flight Loads & Environments Initiative

- Actual Process (Low Frequency / Vibro-Acoustics)



Flight Loads & Environments Initiative

- Actual Process – Some Facts impacting CPMO:
  - PL primary structure sized to LV manual load factors (no project-specific design criteria from LV)
  - PL subsystems, components, secondary structure designed to project prescribed quasi static load factors (QSLF) or mass acceleration curve (MAC) where vibro-acoustics are included
  - The CLA does not have a design impact (no CPMO impact).
  - The CLA has a verification role.
  - Components usually driven by random vibration levels (ranging from minimum workmanship to best estimates BEA/SEA)
  - Most of the requirements are acceleration based (indirect)

Flight Loads & Environments Initiative

- Historical Background
  - Late 80's: Force sensors availability and start to use them in getting test interface force measurements (TOPEX)
  - 1990:
    - Force limiting analysis techniques for random vibration pioneered by JPL in the early 1990's.
    - Force limiting analysis techniques adopted by GSFC and Industry in the mid 1990's.
    - Sine and random vibration force limited testing became standard at GSFC, JPL, Industry (Component to Observatory level). This brought a decrease in dynamic test loads and analyst/project increase in confidence in dynamic models and testing.
  - 2000: Time to move force measurements to LVs and get force / acceleration response flight measurements and reconcile them with simulations.

Flight Loads & Environments Initiative

- Some facts/findings on dynamic loads/environments:

  1) It has been proven by ground / flight force measurements and force limiting analysis / test techniques that the random acceleration environments are very conservative and the source of unnecessary time and resources spent during the design phase and the cause of many unnecessary test failures

Flight Loads & Environments Initiative

- Some facts /findings on dynamic loads/environments:

2) There is a lack of field validation of coupled systems (LV + PL) Finite Element Models

3) There is a consensus that Coupled Loads Analysis (CLA) damping values are conservative

4) There are not force / acceleration flight measurements available to assess PL flight loads and environments and perform reconstructions. It is not possible to correlate or evaluate the predicted PL responses without a corresponding flight measurement.

Flight Loads & Environments Initiative

- Some facts findings on dynamic loads/environments:

5) Current flight reconstruction is limited to parameters such as gimbal and avionics section accelerations, chamber pressure measurements, PL acoustic levels. The actual structural design parameters of PL interface forces and acceleration responses are not reconciled.

6) Flight interface force and response acceleration reconciliation has a much higher added value to structural design and verification than avionics section acceleration reconciliation.

Flight Loads & Environments Initiative

- Some facts/findings on dynamic loads/environments:

7) New dynamic loads events have emerged in the last two years (mid frequency range) without clear understanding of root causes and remedy, impacting schedule, cost and eventually risking hardware if tested (Delta2 HF MECO 80-130 Hz, Pegasus 2nd Stage 70 Hz). Still the phenomena is judged by the interface acceleration and there is a a lack of valuable response data.

Flight Loads & Environments Initiative

- Some facts/findings on dynamic loads/environments:

  8) Loads process has not changed significantly since the space age began. No appreciable loads reductions / processes improvements to support PL design have been presented to the PL community.

  9) The PL design process is essentially an open loop exercise which many people feel is overly conservative.

Flight Loads & Environments Initiative

- Some facts/findings on dynamic loads/environments:

10) The value of the current loads and environments process is:
   a) showing potential PL loads/environments exceedances with respect to design
   b) Impacting PL testing
   c) PL Verification / Compliance.

   In most of the cases the process is ineffective in impacting design and CPMO.

11) New Agency Space Exploration Initiatives require(s) a reduction of CPMO.

Flight Loads & Environments Initiative

- Some facts/findings on dynamic loads/environments:

12) There is a lack of operational dynamic loads measurements and as a consequence an inherent limitation to improvement of the dynamic loads processes.

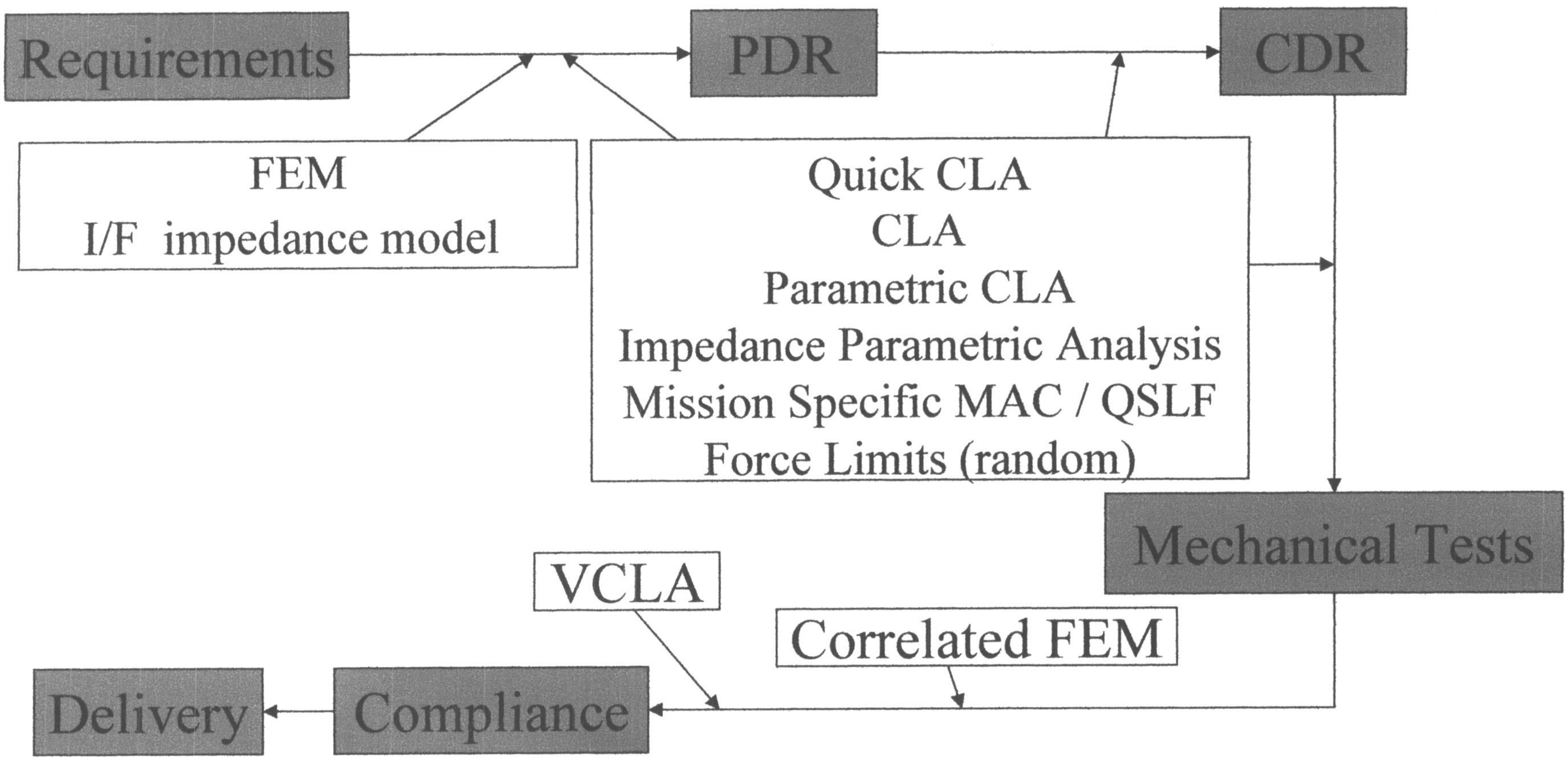
13) Design and test as you fly would get closer if operational force / response acceleration measurements were available to assist loads/environments processes and assist the PL in design and verification.

Flight Loads & Environments Initiative

- Proposed Process (Low Frequency / Vibro-Acoustics)
  - To reduce CPMO, impact design
  - To impact design, improve actual loads and environment processes and develop new processes that can timely support the PL design cycle
  - To improve actual loads and environment processes and develop new processes, obtain PL to LV flight interface forces and response acceleration/forces from “n” flights on the same LV. Then reconstruct those flights reconciling those parameters.

Flight Loads & Environments Initiative

Proposed Process (project milestones perspective view)



Flight Loads & Environments Initiative

Quick CLA

- Requested any time during the PL cycle
- Input: PL FEM
- Quick turnaround
- Output: Reduced set

Parametric CLA:

- Mainly before PDR
- Input: PL FEM and list of parameters
- Output: Reduced set

Flight Loads & Environments Initiative

Impedance Parametric Analysis

- Mainly before PDR
- Input: PL Interface and Transfer Impedances
- Quick turnaround
- Assist mission specific QSLF
- Outputs:
  - Coupled LV/PL impedance per flight event
  - Force limits per flight event / frequency range
  - Force limits at instruments / subsystems per flight event

Flight Loads & Environments Initiative

Mission Specific MAC / QSLF

- Mainly before PDR
- Input: PL FEM
- Output:
  - Mission specific MAC
  - Mission specific QSLF (substitute Users Manual Load Factors)

Flight Loads & Environments Initiative

Vibration Force Limits:

- For LV's with Random or Sine Specification at System Level (nearly all LV's)
- Inputs: PL FEM
- Output: Force Limits

- In any case, implement tool to generate force limits to complement each random or sine spec. for components/instrument/subsystems early in the project.

Flight Loads & Environments Initiative

How the new interface force and acceleration response measurements will assist the process:

- Reconciliation of interface force and response acceleration should provide improved understanding of LV and PL models and forcing functions per event

- Identification of coupled LV/PL damping may impact analyses on events that are damping sensitive. LV and PL damping can also be obtained and be of some value / lesson learned.

Flight Loads & Environments Initiative

How the new interface force and acceleration response measurements assist the process:

- The measurement of interface forces (local/global) and accelerations will define LV, PL and coupled system interface and transfer impedance functions per flight event to support impedance parametric analyses

- The measurement of response accelerations will assist the development and understanding of MACs

Flight Loads & Environments Initiative

What does it take to get "n" measurements:

- Get funding and agency (NASA) commitment
- Partners interest: Agency partners, other Government / industry partners (LV manufacturers)
- Make a plan (proposal under consideration) to include:
  - Definition of role and responsibilities of partners
  - Definition of measurement system (architecture, real estate, mechanical, electrical, power, qualification for flight, FMD, etc)

Flight Loads & Environments Initiative

Secondary Objective:

– Design "coupon" force measurement device (in and out of plane capability). For example a piezo-electric embedded into softer material.

– Design force ring (light weight, non intrusive) based on the coupon

– Both coupon and ring can be used for test and flight applications (can become a standard LV flight sensor)